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HELMINTHS OF THE MARBLED GOBY (*POMATOSCHISTUS MARMORATUS*) A MEDITERRANEAN IMMIGRANT IN THE BLACK SEA FAUNA

Yu. Kvach

Odessa Branch of the Institute of Biology of the Southern Seas, NAS of Ukraine,
Pushkinska str., 37, Odessa, 65125 Ukraine
E-mail: kvach@localka.net

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Helminths of the Marbled Goby (*Pomatoschistus marmoratus*), a Mediterranean Immigrant in the Black Sea Fauna. Kvach Yu. — The marbled goby, *Pomatoschistus marmoratus* (Risso, 1810), the Mediterranean immigrant in the Black Sea fauna, was examined for the metazoan parasites. In total, 12 parasite species were found to occurre. The component community consists of 7 trematode species, two nematodes, two acanthocephalans, and one cestode species. Two parasite species (*Aphalloides coelomicola* and *Dichelyne minutus*) were represented by both adults and larvae, four parasite species were presented by adults (*Asymphylodora pontica*, *Paratimonia gobii*, *Acanthocephaloides propinquus*, and *Telosentis exiguus*), and six species were presented by larvae (*Bothriocephalus gregarius*, *Cryptocotyle concavum*, *C. lingua*, *Pygidiopsis genata*, *Timoniella imbutiforme*, and *Contracaecum microcephalum*). *T. imbutiforme* has the great tendency to join the infracommunity. The core of parasite fauna of the marbled goby consists of two specialists, *A. coelomicola* and *P. gobii*, which immigrated to the Black Sea together with their hosts. The co-immigration is a result of co-evolution of the parasites' and host's life cycles.

K e y w o r d s: marbled goby, Black Sea, parasites, Mediterranean immigrants.

Гельминты бычка-лысуна (*Pomatoschistus marmoratus*) — средиземноморского иммигранта в фауне Черного моря. Квач Ю. — Бычок-лысун, *Pomatoschistus marmoratus* (Risso, 1810), — средиземноморский иммигрант в черноморской фауне, обследован на наличие многоклеточных паразитов. Многокомпонентное сообщество лысуна составляют 12 видов паразитов: 7 видов трематод, два — нематод, два — скребней и один вид цестод. Два вида паразитов (*Aphalloides coelomicola* и *Dichelyne minutus*) представлены как взрослыми стадиями, так и личинками, четыре (*Asymphylodora pontica*, *Paratimonia gobii*, *Acanthocephaloides propinquus* и *Telosentis exiguus*) — взрослыми особями, 6 (*Bothriocephalus gregarius*, *Cryptocotyle concavum*, *C. lingua*, *Pygidiopsis genata*, *Timoniella imbutiforme* и *Contracaecum microcephalum*) — личинками. Вероятность обнаружения в составе инфрасообществ наиболее высока для *T. imbutiforme*. Ядро паразитофауны включает в себя два специфичных к лысуну вида, *A. coelomicola* и *P. gobii*, которые иммигрировали в Черное море вместе со своими хозяевами. Совместная их иммиграция является следствием коэволюции жизненных циклов рассматриваемых паразитов и хозяина.

К л ю ч е в ы е с л о в а: бычок-лысун, Черное море, паразиты, средиземноморские иммигранты.

Introduction

The Black Sea fauna consists of the group of Mediterranean immigrants which entered this water body probably within the past 12 000 years (Miller, 1965). One of the common representatives of this faunistic group is the marbled goby *Pomatoschistus marmoratus* (Risso, 1810), which is widely distributed in whole Mediterranean basin (Miller, 1986).

Because of their ecological plasticity, the gobiids are a convenient model for studying the processes of colonization by parasites (Zander, Kesting, 1998). In the Black Sea the gobiid parasite fauna is more heterogeneous than the gobiid fish fauna itself (Naidenova, 1974). The specific parasite fauna, which is not similar to the ones of other gobiid species in the Black Sea, is typical for the marbled goby (Kvach, 2005 a). It consists of the specialists such as *Aphalloides coelomicola* Dollfus, Chabaud et Golvan, 1957 and *Paratimonia gobii* Prévôt et Bartoli, 1967.

The aim of the presented study is to analyse the parasite community of the marbled goby and the role of this fish in the parasite life cycles in the Northwestern Black Sea.

Material and Methods

The gobies were sampled by deep net (100 cm x 50 cm; cell ∅ 5 mm) in 2002–2006 at 8 localities of the Northwestern Black Sea (NWBS): 1. Tyligul Estuary, 46°53' N 31°03' E; 2. Tyligul Estuary, 46°41' N 31°09' E; 3. Tyligul Estuary; 4. Hryhorivsky Estuary, 46°37' N 31°00' E; 5. Khadzhibey Estuary, 46°33' N 30°41' E; 6. Gulf of Odessa, 46°28' N 31°45' E; 7. Sukhyi Estuary, 46°21' N 30°38' E; 8. Budaki Lagoon, 46°01' N 30°24' E (fig. 1). Two water bodies, the Tyligul Estuary and the Budaki Lagoon are isolated from the sea by natural sandbars. The sampling places in the Gulf of Odessa and the Sukhyi Estuary were located in lagoons, artificially isolated from the sea by mooring lines. Only in the Hryhorivsky Estuary the gobies were sampled in the southern part, connected with the open sea.

In total, 108 gobies were examined for metazoan parasites (table 1). The fish were transported alive to the laboratory, put in aquarium, and then executed in two days. The standard length (SL, cm) of fish individual was measured first.

All parasitological nomenclature follows the levels of Bush et al. (1997) and Zander (1998). The prevalence (P, %), intensity (presented as intensity range, IR), mean intensity (MI), and abundance (A) were calculated according to Bush et al. (1997). The importance of the host-parasite relationship, expressed as the status as core or satellite species, is described by abundance: > 2 — core species, 0.6–2 — secondary species; 0.2–0.6 — satellite species; < 0.2 — rare species (Zander et al., 2000; Zander, 2003). The tendency to join the infracommunity was evaluated according to the Infracommunity Index, ICI (Zander, 2004):

$$ICI = \frac{Mij}{Nj \times Ij},$$

where *Mij* was the ratio (numbers) of multiple infected hosts *j* with parasite *i* and other parasites, *Nj* was the ratio (numbers) of infected hosts *j*, and *Ij* was the mean of parasite species in host *j* (= mean

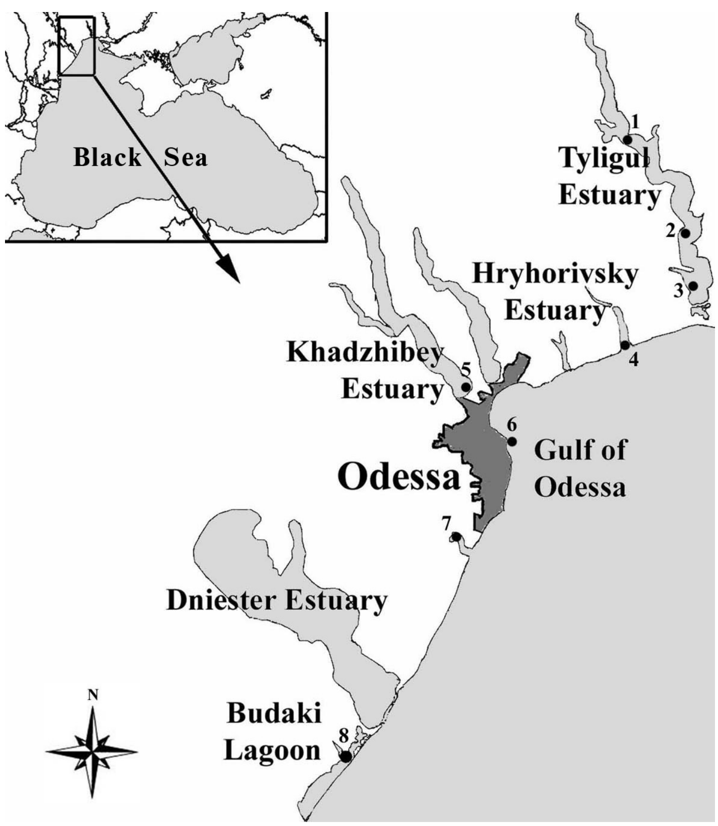


Fig. 1. Schematic map of the investigated area (black circles are sampling localities).

Рис. 1. Схематическая карта района исследований (черными кружками обозначены места сбора материала).

Table 1. The number of examined hosts and its infestation parameters

Таблица 1. Количество исследованных хозяев и параметры их зараженности

Localities	Budaki Lagoon	Sukhyi Estuary	Gulf of Odessa	Khadzhi-bey Estuary	Hryhorivsky Estuary	Tyligul Estuary	Total
Host number	33	8	5	18	7	37	108
SL, cm	3.8 ± 1.0	3.9 ± 2.4	4.2 ± 0.8	2.6 ± 0.2	3.7 ± 0.8	2.3 ± 0.6	3.2 ± 1.2
Prevalence (number / %)	33 / 100	8 / 100	4 / 80	0 / 0	6 / 85.7	37 / 100	88 / 81.5
Number of uninfected hosts	0	0	1	18	1	0	20
Total number of parasites occurred	4586	2638	81	0	57	923	8285
Mean intensity	139.0	329.8	20.3	0	9.5	24.9	94.1
Abundance	139.0	329.8	16.2	0	8.1	24.9	76.7

'Total' column includes the data from the Khadzhibey Estuary, where no metazoan parasites occurred in the marbled goby.

infracommunity). The great tendency to join the community was determined by the ICI level more then 0.30 (Zander, 2004).

The Species Evenness (J) was calculated according to Zander et al. (1993):

$$J = \frac{Hs}{\ln S},$$

where *Hs* is Shannon-Wiener Index, *S* is number of species.

Evenness values > 0.6 mean a greater part of the homogeneity, of > 0.7 a high homogeneity.

Abbreviations of names of parasites life stages were used as follows: pl — plerocercoid, met — metacercaria, L3 — 3rd stage larva.

Results

The maximal number of fishes was caught in the Budaki Lagoon, Khadzibey and Tyligul estuaries (table 1). In the Gulf of Odessa, Hryhorivsky and Sukhyi estuaries the marbled goby was rather rare (5, 7 and 8 fishes respectively).

No metazoan parasites occurred in the marbled goby in the Khadzhibey Estuary. All fishes caught in the Budaki Lagoon, Sukhyi and Tyligul estuaries were infected with parasites (table 1). Four from five examined fishes were infected in the Gulf of Odessa, 6 from 7 in the Hryhorivsky Estuary. The maximal number of parasites and abundance were noted in the Budaki Lagoon.

In total, 12 metazoan parasite species occurred in the marbled goby in the NWBS (table 2). The component community consisted of 7 digenean species, two nematodes, two acanthocephalans, and one cestode species. Two parasite species (*Aphalloides coelomicola* and *Dichelyne minutus* (Rudolphi, 1819)) were presented by both adults and larvae (table 2). Four parasite species were presented by adults, and six by larvae.

Most of parasite species, namely *Bothriocephalus gregarius* Renaud et al., 1983 pl, *Asymphylodora pontica* (Tschernyschenko, 1949), *Paratimonia gobii*, *D. minutus*, *Acanthocephaloides propinquus* (Dujardin, 1845), and *Telosentis exiguus* von Linstow, 1901, were found in the gut of fish. Four parasite species, *A. coelomicola* met, *Cryptocotyle concavum* (Creplin, 1825) met, *C. lingua* (Creplin, 1825) met, *T. imbutiforme* met, occurred in muscles of gobies. Two species from this list (*C. concavum* met and *C. lingua* met) were also found in fins and skin, but one (*A. coelomicola* met) in ovaries. The parasites located in tissues (metacercariae of *A. coelomicola*, *Cryptocotyle* spp., *Timoniella imbutiforme* (Molin, 1859)) were most numerous in the marbled goby (table 2). Three parasite species were found encysted in intestinal walls: *Pygidiopsis genata* Looss, 1907 met, *D. minutus* L3, *Contracaecum microcephalum* (Rudolphi, 1819) L3. Only adults of *A. coelomicola* occurred in the body cavity of gobies.

Two species, *T. imbutiforme* met and *A. propinquus*, occurred in all the water bodies studied (table 2). Such parasites as *B. gregarious* pl, *C. microcephalum* L3, *T. exiguus* were found only in one water body (table 2).

Table 2. Component community of parasites of the marbled goby in the NWBS

Таблица 2. Многокомпонентное сообщество паразитов бычка-лысуна в северо-западной части Черного моря

Localities		Budaki Lagoon	Sukhyi Estuary	Gulf of Odessa	Hryhorivsky Estuary	Tyligul Estuary	Total
				CESTODA			
Bothriocephalus gregarius pl	P				3 from 7		2.8
	IR				2–6		2–6
	MI				4.0±2.0		4.0±2.0
	A				1.7		0.1
				TREMATODA			
Aphalloides coelomicola	P	45.5	3 from 8			10.8	20.4
	IR	1–10	16–36			1–11	1–36
	MI	3.5±3.2	26.0±10.0			4.3±4.6	6.7±9.0
	A	1.6	9.8			0.5	1.4
A. coelomicola met	P	27.3				10.8	12.0
	IR	1–10				1–20	1–20
	MI	4.0±3.0				7.0±8.8	4.9±5.2
	A	1.1				0.8	0.6
Asymphylodora pontica	P		2 from 8			13.5	6.2
	IR		1			1–15	1–15
	MI		1.0±0.0			6.8±6.3	5.1±5.9
	A		0.3			0.9	0.3
Cryptocotyle concavum met	P	69.7	7 from 8		2 from 7	54.1	48.1
	IR	2–70	9–1000		1	1–41	1–1000
	MI	21.0±16.8	319.7±465.2		1.0±0.0	6.4±9.0	54.8±191.8
	A	14.6	279.8		0.3	3.4	26.4
C. lingua met	P	57.6				32.4	28.7
	IR	1–9				1–13	1–13
	MI	4.7 ± 2.2				3.6 ± 3.8	4.3 ± 2.9
	A	2.8				1.2	1.2
Paratimonia gobii	P	6.1	5 from 8	1 from 5		32.4	18.5
	IR	1–3	1–50	44		1–80	1–80
	MI	2.0 ± 1.4	19.8 ± 20.4	44.0		17.3 ± 22.3	17.7 ± 20.9
	A	0.1	12.4	8.8		5.6	3.3
Pygidiopsis genata met	P	57.6	3 from 8				20.4
	IR	3–24	31–46				3–46
	MI	10.6±5.8	40.0±7.9				14.6 ± 11.9
	A	6.1	15.0				3.0
Timoniella imbutiforme met	P	100.0	3 from 8	2 from 5	6 from 7	94.6	73.1
	IR	57–210	30–36	3–19	2–6	2–61	2–210
	MI	112.3 ± 37.8	33.0 ± 3.0	11.0 ± 11.3	4.5 ± 1.4	12.9 ± 14.7	54.5 ± 60.1
	A	112.4	12.4	4.4	3.9	12.2	39.9
				NEMATODA			
Dichelyne minutus	P		1 from 8	3 from 5	4 from 7	2.7	8.3
	IR		1	3–5	1–6	2	1–6
	MI		1.0	4.0 ± 1.0	3.0 ± 2.2	2.0	3.0 ± 1.7
	A		0.1	2.4	1.7	0.05	0.3
D. minutus L3	P				1 from 7		0.9
	IR				1		1
	MI				1.0		1.0
	A				0.1		0.01
Contracaecum microcephalum L3	P	3.0					0.9
	IR	1					1
	MI	1.0					1.0
	A	0.03					0.01
				ACANTHOCEPHALA			
Acanthocephaloides propinquus	P	18.2	1 from 8	2 from 5	1 from 7	8.1	12,0
	IR	1–2	1	1–2	1	1–12	1–12
	MI	1.3 ± 0.5	1.0	1.5 ± 0.7	1.0	4.7 ± 6.4	2.1 ± 3.0
	A	0.2	0.1	0.6	0.1	0.4	0,3

Table 2 (continued).
Окончание таблицы 2.

Localities		Budaki Lagoon	Sukhyi Estuary	Gulf of Odessa	Hryhorivsky Estuary	Tyligul Estuary	Total
				ACANTHOCEPHALA			
Acanthocephaloides propinquus	P	18.2	1 from 8	2 from 5	1 from 7	8.1	12,0
	IR	1–2	1	1–2	1	1–12	1–12
	MI	1.3 ± 0.5	1.0	1.5 ± 0.7	1.0	4.7 ± 6.4	2.1 ± 3.0
	A	0.2	0.1	0.6	0.1	0.4	0,3
Telosentis exiguus	P				1 from 7		0,9
	IR				2		2
	MI				2.0		2,0
	A				0.3		0,02
Species richness	8	8	4	6	8	12	
Shannon Index	0.72	0.64	1.09	1.33	1.45	1.20	
Species Evenness	0.35	0.31	0.79	0.74	0.70	0.48	

'Total' column includes the data from the Khadzhibey Estuary, where no metazoan parasites occurred in the marbled goby.

The parasite component communities of the Tyligul and Hryhorivsky estuaries are presented by all types by its host-parasite relationships: core, secondary, satellite, and rare (fig. 2). In the Sukhyi Estuary and the Budaki Lagoon the secondary species were absent, but in the Gulf of Odessa no satellite and rare species occurred. The core species were found in all water bodies (except the Khadzhibey Estuary where no metazoan parasite was found). The number of the core species in the component community varied from one (in the Hryhorivsky Estuary) to five (in the Sukhyi Estuary and the Budaki Lagoon) (fig. 2). In the Budaki Lagoon a part of core was taken by digeneans *C. concavum*, *C. lingua*, *P. genata*, and *T. imbutiforme* (table 2). In addition, sum-

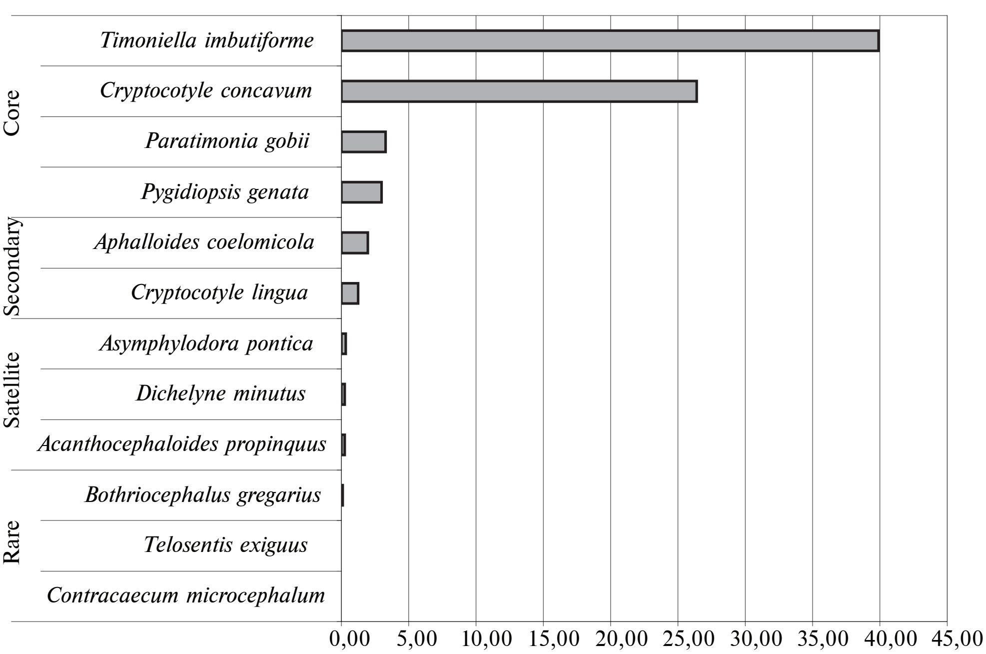


Fig. 2. The number of core, secondary, satellite, and rare species in the parasite component community of the marbled goby in the various water areas of the NWBS.

Рис. 2. Количество основных, второстепенных, сателлитных и редких видов в многокомпонентном сообществе паразитов бычка-лысуна в различных водоемах северо-западной части Черного моря.

marising the adults and larvae of *A. coelomicola*, this species took a part of core, too (A = 3.46). *C. microcephalum* and *A. propinquus* were rare in the Budaki Lagoon. Four parasite species (*C. concavum*, *P. gobii*, *P. genata*, and *T. imbutiforme*) were core in the Sukhyi Estuary, but *A. pontica* and *A. propinquus* were satellite (table 2). In the Gulf of Odessa the digeneans *P. gobii*, *T. imbutiforme*, and the nematode *D. minutu*s were core, but the acanthocephalan *A. propinquus* was secondary species in the parasite community. Only *T. imbutiforme* was core in the Hryhorivsky Estuary, *B. gregarius* and *D. minutus* (for adults and larva the summarised A = 1.9) were secondary, *C. concavum* and *T. exiguus* were satellite, and *A. propinquus* was rare. In the Tyligul Estuary *C. concavum*, *P. gobii*, and *T. imbutiforme* were core species, *A. coelomicola* (for adults and larvae the summarised A = 1.2), *A. pontica*, and *C. lingua* were secondary, *A. propinquus* was satellite, and *D. minutus* was rare (table 2). In total, in the NWBS the core species were *C. concavum*, *P. gobii*, *P. genata*, and *T. imbutiforme*, secondary species were *A. coelomicola* and *C. lingua*, satellite species were *A. pontica*, *D. minutus*, and *A. propinquus*, other species were rare (fig. 3).

The parasite fauna was presented by five types of infracommunities with the species numbers from one to six (fig. 4). In the Budaki Lagoon the parasite fauna was presented by all types of infracommunities and most of examined fishes were infected with four and more parasite species. In the Tyligul Estuary most of examined fishes were infected with one to three parasite species. The fishes infected with only one parasite species were relatively rare, from two individuals in the Hryhorivsky and Sukhyi estuaries and the Gulf of Odessa, to six individuals in the Tyligul Estuary. Only one species, *T. imbutiforme*, had great tendency to join the infracommunity in the Tyligul Estuary (table 3). This parasite also had high ICI in other water bodies, except the Sukhyi Estuary, and maximal tendency to join the community for the total NWBS (ICI = 0.29).

The greater part of the homogeneity of the parasite component community was mentioned in the Gulf of Odessa, Hryhorivsky, and Tyligul estuaries (table 2). In the

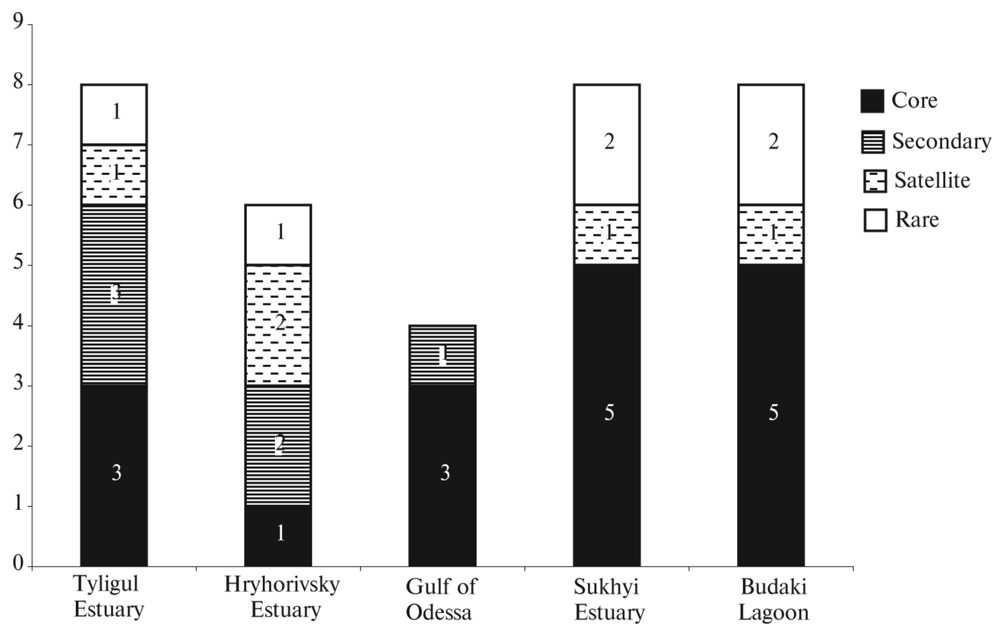


Fig. 3. The abundance of different parasite species in the *Pomatoschistus marmoratus* parasite fauna by categories: core, secondary, satellite, and rare.

Рис. 3. Обилие различных видов паразитов в паразитофауне *Pomatoschistus marmoratus* по категориям: основные, второстепенные, сопутствующие, редкие.

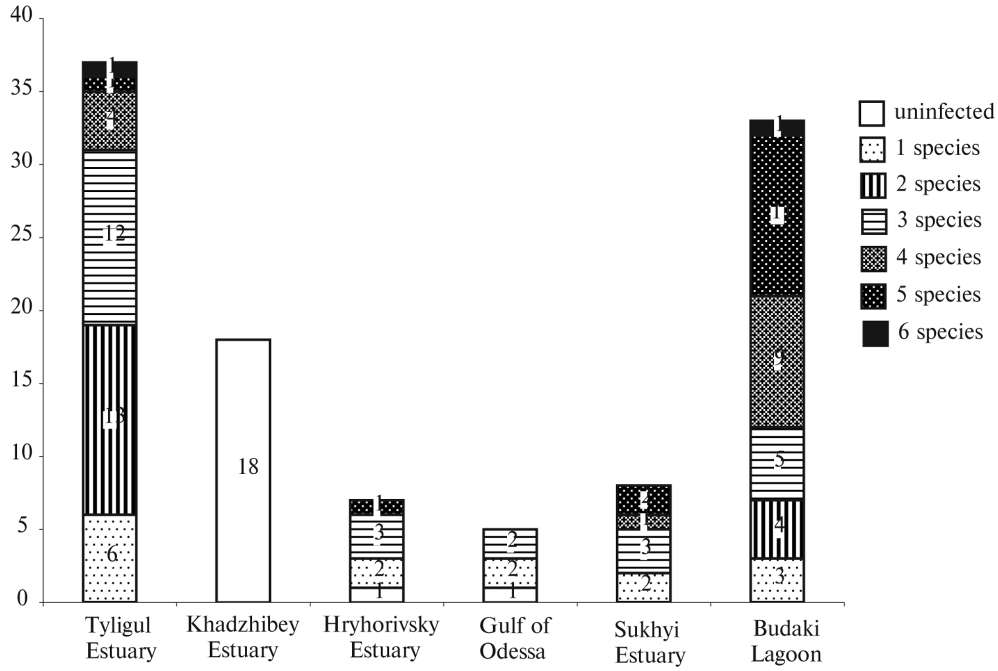


Fig. 4. The part of different infracommunities in the parasite fauna of the marbled goby in different water bodies of the NWBS.

Рис. 4. Доля различных инфрасообществ в паразитофауне бычка-лысуна в различных водоемах северо-западной части Черного моря.

Budaki Lagoon and Sukhyi Estuary it was low. In total, the low homogeneity was typical for the parasite component community of the marbled goby in the NWBS.

Discussion

Twenty-seven metazoan parasite species have been mentioned in the Black Sea basin according to data of different authors (Radulescu, 1953; Chernyshenko, 1960, 1962, 1966; Chernyshenko, Sventsytskaya, 1970; Naidenova, 1974; Machkevsky et al., 1990). We found 17 parasite species, 15 of which had already been mentioned in published data, but two species, *Asymphylodora pontica* and *Cryptocotyle lingua* met, were mentioned from the marbled goby for the first time.

The absence of metazoan parasites in the Khadzhibey Estuary was caused by its low salinity (~ 3‰). All of parasites typical for the marbled goby have marine or brackish water origin. The absence of digeneans, which are core of the marbled goby parasite fauna, was caused by lack of mollusks in the fauna of the Khadzhibey Estuary (Kvach, 2004).

The relative abundance of the various parasite species was the highest in the Gulf of Odessa, where the species richness was the lowest (table 2). All parasite species in this water body, except *Paratimonia gobii*, had similar tendency to join the community, ICI = 0.25 (table 3).

The digenean *Asymphylodora pontica* is a specific parasite of gobiids in the Black Sea, infecting mostly neogobiins, such as the round goby *Apollonia melanostoma*, and the monkey goby *A. fluviatilis* (Gaevskaya et al., 1975; Kvach, 2005 a). However, the case of infestation of gobiin fish (a grass goby *Zosterisessor ophiocephalus* from the Hryhorivsky Estuary) was mentioned by Yu. Kvach (2005 b). In both cases (occurrence in the marbled and grass gobies) we can consider it as an occasional infestation.

Table 3. Infracommunity indices
Таблица 3. Индексы инфрасообщества

Localities	Budaki Lagoon	Sukhyi Estuary	Gulf of Odessa	Hryhorivsky Estuary	Tyligul Estuary	Total
Mean infracommunity	3.7 ± 1.4	3.1 ± 1.6	2.0 ± 1.2	2.8 ± 1.8	2.6 ± 1.1	3.1 ± 1.5
Bothriocephalus gregarius pl				0.18		0.01
Aphalloides coelomicola	0.16	0.12			0.07	0.11
Asymphylodora pontica		0.08			0.05	0.03
Cryptocotyle concavum met	0.19	0.28		0.12	0.21	0.19
C. lingua met	0.15				0.13	0.11
Paratimonia gobii	0.02	0.20	0.13		0.13	0.07
Pygidiopsis genata met	0.15	0.12				0.08
Timoniella imbutiforme met	0.27	0.12	0.25	0.29	**0.37**	0.29
Dichelyne minutus		0.04	0.25	0.24	0.01	0.004
Contracaecum microcephalum L3	0.01					0.03
Acanthocephaloides propinquus	0.04	0.04	0.25	0.06	0.02	0.05
Telosentis exiguus				0.06		0.004

Note. Bold: the great tendency to join the infracommunity.

The marbled goby plays important role in the realization of the life cycle of the cestode *Botriocephalus gregarius* and the digenean *Timoniella imbutiforme*. Both species are generalists on the larval stage. In the Mediterranean Sea *B. gregarius* uses the marbled goby as main paratenic host, but the definitive host is the turbot *Psetta maxima* (Robert et al., 1988). In the NWBS this species occurred in the Hryhorivsky Estuary only. This is a water body connected with the sea by 15-m depth navigation canal, which is a suitable habitat for turbots. The *T. imbutiforme* met is a numerous parasite species occurring in all the water bodies examined (table 2). This is only parasite species which has great tendency to join the infracommunity, but only in the Tyligul Estuary, where the highest diversity of parasites was noted according to the Shannon Index (table 2, 3). The gobiids serve as second intermediate hosts of this parasite, together with other small-sized fishes, such as Atherinidae (Maillard, 1973 a).

The marbled goby is an annual fish species, which dies after spawning (Miller, 1986; Smirnov, 1986). The small sizes of this fish makes it the suitable pray item for many species of predatory fish and fish-eating birds. This fact influents the parasite fauna of this goby. So, the core species in the parasite component community are mostly metacercariae, such as *Cryptocotyle* spp., *Pygidiopsis genata*, *T. imbutiforme* (table 2). Also, in the core of the parasite fauna are two parasites specific for genera *Pomatoschistus* and *Knipowitschia*: *Aphalloides coelomicola* and *P. gobii* (table 2). The marbled goby plays a role of both definitive and second intermediate host for *A. coelomicola* (Maillard, 1973 b). The adults are located in the body cavity, and the metacercariae are in the ovaries and muscles of the same fish. This parasite is well adapted to the life cycle of the gobies and the necessary condition for the transmission of the digenean is the host death (Pampoulie et al., 2000). The infestation of *Pomatoschistus* with *P. gobii* is a case of adaptation of the parasite life cycle to the specific diet of the host. The metacercariae of *P. gobii* are located in inhaling siphons of mussels *Abra ovata* and *Cerastoderma glaucum* (Maillard, 1975). The small-sized gobies, such as the marbled goby, can use the cut-off siphons as the pray item.

So, among the core species of the parasite fauna of the marbled goby in the studied NWBS lagoons and estuaries are not only generalists, as *Cryptocotyle* spp. or *T. imbutiforme*, but also specialists, such as *A. coelomicola* and *P. gobii*. Both specialists have Mediterranean origin, as well as their hosts. This is a marked difference between the marbled goby and other Black-Sea gobiids, the core of which parasite fauna consists of generalists only (Kvach, 2005 a; Kvach, Oğuz, 2009). The infestation of the marbled goby with two above mentioned specialist trematode species is a result of co-evolution,

supporting the 'Red Queen Hypothesis' of L. Van Valen (1973). During the co-evolution the adaptation of the life cycles of parasites to the specific life cycle of host (the marbled goby is annual small-sized fish) was completed. It was a cause of successful co-immigration of the marbled goby and its specific parasites to the Black Sea.

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